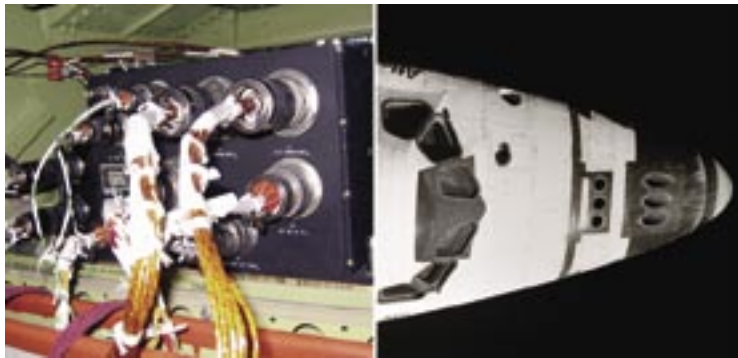


# NESC Assessments Yield Lessons Learned for the Agency

## Space Shuttle Reaction Jet Driver (RJD)

The Space Shuttle RJD avionics boxes control the thrusters that are used to maneuver the vehicle. A failed-on primary thruster for as little as two seconds during mated operations with the International Space Station could be catastrophic. The zero-fault tolerant RJD circuit design violates Space Shuttle Program requirements for a two-fault tolerance of critical systems. In addition, potential age degradation of RJD transistors and wiring were unknown. The NESC conducted extensive reviews, analyses, tests and inspections to determine the RJD inadvertent firing risk. Testing of flown RJD transistors revealed no age concerns and a modified box-level health check was instituted.

**Lesson:** When extending components beyond their original design life, adequate screens for aging and/or degradation should be performed.



*RJD electronics box and Orbiter primary thrusters (three primary thrusters are visible closest to the nose cap on Atlantis).*

## International Space Station (ISS) Modules Post Proof Non Destructive Evaluation (NDE)

The NESC was requested to determine associated risks and potential acceptance rationale of not performing post proof NDE on five European manufactured ISS modules. These modules were considered pressure loaded structures and not pressure vessels, thus allowing the use of leak-before-burst (LBB) criteria as a substitute for post proof NDE. The reliance on LBB criteria reduces the potential for detection of unacceptable weld flaws that could extend to a critical crack size and module rupture without adequate operational controls. In addition, the original structural analysis did not incorporate local stress magnifications from allowable weld peaking and mismatch features. After extensive evaluation, the NESC recommended performing specialized analyses to assess both the weld as-designed and nonconformance conditions. This approach was augmented with empirical testing and statistical examination of inspection data from applicable welded structures.

**Lesson:** While the use of LBB criteria as a design characteristic is acceptable, complex welded structures should be assessed using safe-life analysis techniques that utilize post proof NDE results as well as weld drawing/specification allowable dimensional characteristics.



*Gaseous Helium COPVs installed in the Orbiter's Orbital Maneuvering System.*

## Composite Overwrapped Pressure Vessels (COPV)

The NESC was tasked to evaluate the flight rationale for the Orbiter Kevlar/Epoxy COPVs. As part of the evaluation, the NESC examined the Space Shuttle Program's (SSP) Fleet Leader COPV, which had been pressurized under test conditions for 26 years. Also examined were flight hardware design certification and qualification test results, fleet leader test results, and stress rupture test results. The NESC determined that there is significantly less stress rupture life margin remaining in the SSP COPVs than was previously assumed. The NESC assisted the Orbiter Project Office by: 1) accurately assessing the risk of COPV stress rupture failure, 2) developing flight rationale for return-to-flight, and, 3) outlining plans for future tests to complete COPV hardware certification for the future life of the SSP.

**Lesson:** Increased use of composite structures in spacecraft requires comprehensive test programs to better understand potential failure modes like stress rupture. Future spaceflight programs should ensure that provisions for adequate long-term testing are included in the project requirements.



*Chris McGougan (MSFC) performs a weld peaking and mismatch measurement of a simulated ISS aluminum Variable Polarity Plasma Arc weld.*

## Huygens Probe Entry, Descent and Landing (EDL)

The Cassini/Huygens mission is a joint effort between NASA and the European Space Agency (ESA) to explore Saturn and its satellites. NASA experts voiced concerns to the NESC about portions of the Huygens probe EDL, based on experience and lessons learned. As a result, the NESC was actively involved in the EDL analysis focusing on the parachute deployment trigger performance and the resultant effects on the operation of the parachute system. The NESC also evaluated ESA's prediction of the aerodynamic and radiative heating environment to be encountered by the probe at Titan and the corresponding thermal protection system response.

The NESC's assessment of the Huygens probe EDL on Titan included both a data review and independent analyses. The assessment results were shared with the Cassini program and with ESA. Concurrent reviews led by the Jet Propulsion Laboratory and ESA, relied on the NESC EDL assessment results to formulate a recommendation to not change any mission parameter. The recommendation was accepted and the Huygens probe was released nominally on December 24, 2004. A successful EDL was executed on January 14, 2005.

**Lesson:** State-of-the-art tools and methods currently available to NASA, particularly in aeroheating, were only marginally sufficient to conduct this assessment in the time allotted. Future interplanetary EDL analyses should be identified and initiated early enough to allow adequate time to complete the required analysis.



*Artist rendition of the Huygens probe landing on Titan. Critical entry, descent and landing events were modeled by the NESC.*

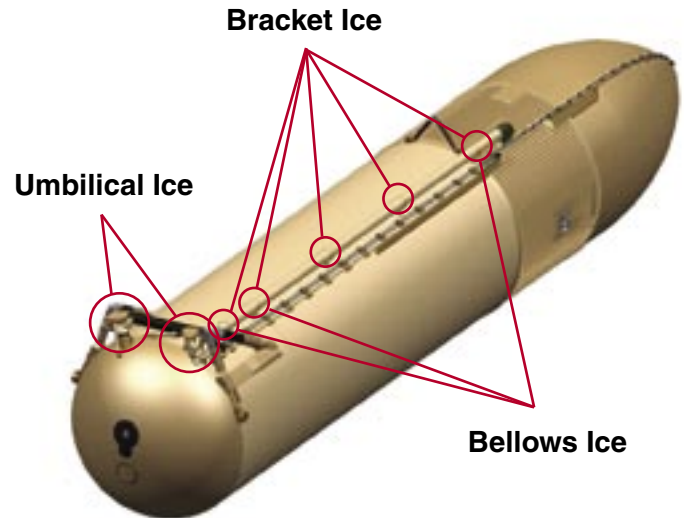
## Peer-Review of the Space Shuttle System Flight Rationale for Expected Debris

Work recently completed by the Orbiter and External Tank (ET) engineering teams indicated that the Space Shuttle System could not be fully certified for flight through expected foam or ice debris liberated from the ET. Therefore, the flight rationale must be based on an accepted risk strategy. The Space Shuttle Program requested that the NESC perform a peer-review of the flight rationale strategy and the supporting engineering data.

The NESC assessed the flight rationale logic for expected debris and identified the limitations and gaps in the supporting engineering data. The assessment included the standard deterministic methods to compute the impact capability of the Orbiter's reinforced carbon-carbon (RCC) and tile - (C); the foam and ice debris environment - (E); the Orbiter impact capability margin - (C/E); and the Monte Carlo-based probabilistic estimate of the likelihood of critical impact of foam and ice debris damage to the Orbiter.

The probability of critical damage to the Orbiter nose cap and wing leading edge RCC was found to be sufficiently low enough to classify the risk as remote or improbable, depending on the debris source. Additionally, the higher risk of critical damage to Orbiter tile from sources of foam debris and from ice debris (feedline brackets, mid and aft feedline bellows, and umbilicals) are categorized as infrequent. However, the ice controls specified in the Launch Commit Criteria are deemed adequate to render the risks acceptable. As new data becomes available from STS-114, the probabilistic risk assessment will need to be updated.

**Lesson:** Comparing the operational environment with the certification requirements of a spacecraft, and resolving any discrepancies, must be a continuous process throughout the life of the spacecraft.



*The NESC reviewed models for predicting damage to RCC and tile caused by foam and ice being shed from the ET during ascent.*

## Peer-Review of the Math Model Tools for On-Orbit Assessment of Impact Damage to the Orbiter Thermal Protection System (TPS)

The Space Shuttle Program requested that the NESC perform a peer-review of the Orbiter damage assessment tools (math models). A pre-flight and on-orbit assessment strategy involving a combination of new and existing math model tools was developed to determine the impact and damage tolerance of the Orbiter TPS (accrete tiles and reinforced carbon-carbon on the nose cap and wing leading edges) due to impacts from expected debris.

The NESC peer-reviewed an engineering data package for each math model tool. The peer-review included an assessment of the end-to-end, integrated analysis strategy to address the compatibility of data exchange between the models and the propagation of uncertainties from the initial definition of the impact event to the final estimate of the resulting damage.

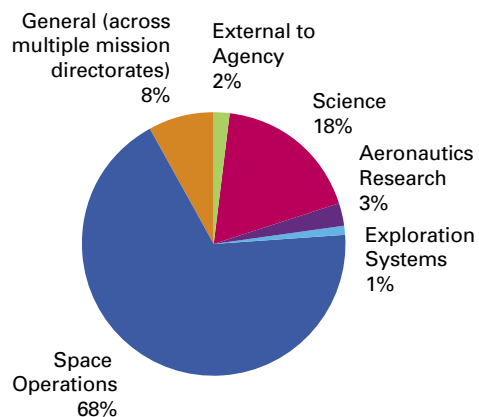
The damage assessment tools were found to be acceptable for supporting return-to-flight. However, technical limitations in the use of each damage assessment modeling tool were identified.

**Lesson:** A comprehensive test program, using design of experiments logic, is required to adequately verify and validate complex math model tools.

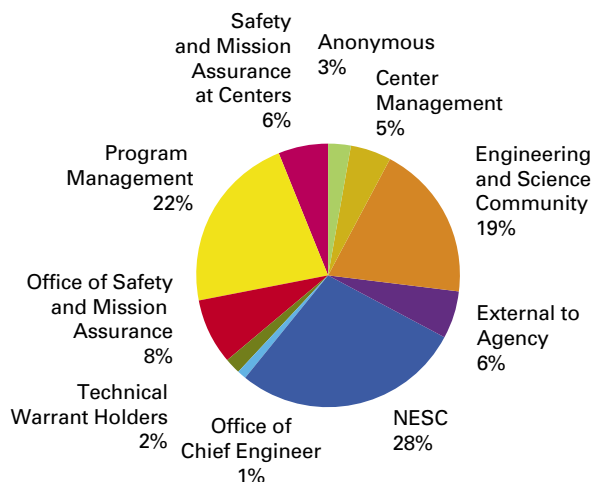
## Metrics

As of July 7, 2005, the NESC has applied its technical expertise to 88 requests.

### NESC Accepted Requests by Mission Directorate



### Sources of NESC Accepted Requests



## Challenging Opportunities Within the NESC are Now Available

The NESC coordinates and conducts robust, independent engineering and safety assessments of high-risk programs across the Agency. To accomplish this goal, the NESC is staffed with high-grade, high-performing scientists and engineers who are experts in their fields. A key component to the continued success of this organizational model is that an individual's assignment to the NESC is limited to approximately 2 years, allowing them to broaden their experience and perspectives before returning to key leadership roles at the Centers. Vacancy announcements for the NESC's senior level positions are currently accessible through the NASA Jobs website at [www.nasajobs.nasa.gov](http://www.nasajobs.nasa.gov). The NESC is located at the Langley Research Center in Hampton, Virginia, with employees residing at the 10 NASA Centers and Headquarters.

For more information on the NESC, the contents of this brief, or to report a technical concern, please visit our Web site: <http://nesc.nasa.gov>

NP-2005-07-65-LaRC

## NESC Honor Awards

NESC honor awards were presented to individuals and teams who significantly contributed to the NESC mission.



NESC Honor Awards October 26, 2004 (Redondo Beach, California).

From left: Ralph Roe (NESC Director/presenter), Phillip Hall (MSFC), Dr. Paul Munafò (MSFC), Dr. Jeffrey Scargle (ARC), Michael Massie (Boeing), Jerry Ross (NESC Chief Astronaut/presenter). Not pictured is Robert Piascik (LaRC).



NESC Honor Awards, February 8, 2005 (Hampton, Virginia).

Cassini/Huygens Probe Entry, Descent and Landing Independent Technical Assessment Team. The NESC Director's Award was presented to Richard Powell (back row far left) and the NESC Group Achievement Award was presented to all team members by Roy Bridges, LaRC's Center Director (front row, second from left).



NESC Honor Awards, June 7, 2005 (Williamsburg, Virginia).

Front row from left: Dr. Michael Nemeth (LaRC), Robert Wingate (MSFC), Pat McLaughlan (JSC), Kay Channell accepting for Dewey Channell (JSC retired), Lorie Grimes-Ledesma (JPL), Philip Deans (JSC). Back row from left: Hank Rotter (JSC) accepting for Dr. Eugene Ungar (JSC), Ralph Roe (NESC Director/presenter), Dr. Stuart Phoenix (Cornell University), Andreas Dibbern (KSC) accepting for James Fesmire (KSC), and Jerry Ross (NESC Chief Astronaut/presenter).

## NASA Engineering and Safety Center (NESC) Data Mining and Trending Working Group

The NESC is currently leading the Agency's efforts to perform independent data mining and trend analysis to identify unknown indicators of future problems. One of the NESC's goals is to perform independent analyses within programs and across programs, not to duplicate the program-specific trending efforts. Through a series of workshops, the NESC has developed working relationships with data mining and statistical experts within academia, industry, and other government agencies. The NESC's collaboration with other organizations will help to ensure that results are maximized and lessons learned from previous efforts are incorporated.

This fall, the NESC will establish a Data Mining and Trending Working Group that will include representatives from all NASA Centers and external experts. This group will assist NASA organizations in strengthening trending activities for the Agency's programs and projects. Another goal of the working group is to improve communications across the Agency in the areas of data mining, trending, and statistics by sharing ideas, methods, technologies, processes, tools, and lessons learned.

## NESC Developing Alternative Methods to Mitigate the Risk from Ice on the External Tank (ET)

The NESC is developing designs that mitigate the risk to the Orbiter from ice debris shed by the ET during ascent. Potentially damaging ice can grow on components of the ET once it is filled with cryogenic hydrogen and oxygen. In particular, the liquid oxygen (LOX) feedline bellows and LOX feedline support brackets are susceptible to the formation of ice because only a limited amount of thermal protection can be applied while still allowing for the required motion of the bellows and brackets.

Through the use of a shrink wrap film filled with nanogel insulating beads, the formation of ice on the LOX feedline bellows was prevented under worst-case temperature and humidity environments during preliminary testing. This design allows the bellows to move normally and the insulating system to separate from the bellows early in flight. Additionally, special coatings for the feedline brackets are being developed to influence the formation and adhesion of ice. Initial laboratory tests have shown that coatings can alter the ice adhesion strength and structural integrity. Ice liberation tests that rely on launch acoustic and vibration loads will be used to evaluate the effectiveness of candidate coatings.



Left: James E. Fesmire (KSC Cryogenic Laboratory Lead-rear left) and Ray E. Patrick (Director of Research and Development, Sealed Air Corporation) make final adjustments of the nanogel sacrificial retainer system on a LOX feedline bellows test article prior to environmental testing. Right: Coated panels at MSFC are used to measure ice adhesion strength and potential reduction of ice structural integrity due to additives in the coatings.

